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COMMERCIAL BORDEAUX MIXTURES

HOW TO CALCULATE THEIR VALUES

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BORDEAUX MIXTURE is the only reliable preventive for certain diseases of plants and must be used despite the present high price of copper sulphate.

Since commercial Bordeaux mixtures vary widely in copper content it is necessary for the grower to know their strength in terms of the amount of equivalent copper sulphate in 50 gallons when diluted.

This can be easily calculated by the method described in this bulletin or can be approximately determined without calculation by reference to Tables I and II.

After the strength of the product is known, the relative money value of its ingredients can be easily calculated.

Physical properties, such as adhesiveness, texture, spreading quality, and rate of settling, also are important factors in determining the efficiency of Bordeaux mixtures.

The grower should regard spraying as an insurance and preventive and should always be prepared for an epidemic of the disease he expects to combat. If he wishes to insure good control, he should, therefore, use a preparation equivalent to the standard Bordeaux mixture recommended for that purpose.

COMMERCIAL BORDEAUX MIXTURES: HOW TO CALCULATE THEIR VALUES.

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BORDEAUX MIXTURE THE ONLY REMEDY FOR CERTAIN DISEASES.

AS A RESULT of the present high price of copper sulphate many farmers who are compelled to combat such diseases as late-blight of the potato, black-rot of the grape, and bitter-rot and blotch of the apple are asking the question, "What can we use as a substitute for Bordeaux mixture?" In answer to this question it can be said that so far as at present known the diseases mentioned can be controlled satisfactorily only by Bordeaux mixture or some other preparation containing copper in some form as the principal active ingredient.

COMMERCIAL BORDEAUX MIXTURES.

COMPARISON OF RELATIVE MERITS.

In looking around for the most economical way out of this difficulty, many are making inquiry as to the true value and relative merits of the various commercial Bordeaux mixtures, pastes, and powders found on the market. It may therefore be helpful to give certain information which will enable the buyer to calculate for himself from analyses stated on their labels the value of any commercial Bordeaux mixture or similar copper fungicide, expressed in terms of the cost of the materials used.

METHODS USED TO CALCULATE VALUES.

Ordinarily, the grower expresses the strength of his homemade Bordeaux mixture in terms of the crystallized copper sulphate ($CuSO_4 5H_2O$; bluestone or blue vitriol) and of the lime in 50 gal-

lons of the prepared spray. Thus, a formula may be stated as a 4–4–50 mixture, meaning that 4 pounds of crystallized copper sulphate and 4 pounds of lime are used with enough water to make 50 gallons.

The insecticide act of 1910[1] requires that—

> In the case of insecticides (other than Paris greens and lead arsenates) and fungicides the labels accompanying such preparations in interstate commerce must contain a plain, correct statement of the name and percentage amount of each and every inert ingredient, or in lieu of this the manufacturer may "at his discretion state plainly upon the label the correct names and percentage amounts of each and every ingredient of the insecticide or fungicide having insecticidal or fungicidal properties, and make no mention of the inert ingredients, except in so far as to state the total percentage of inert ingredients present."

The only feasible method of complying with the above requirements in the case of Bordeaux mixtures[2] is for the manufacturer to include on his label some such statement as the following:

> Active ingredient: Copper, —— per cent.
> Inert ingredient: ———, —— per cent.

METHOD OF CALCULATING INGREDIENTS.

The grower should therefore find on every label of Bordeaux mixture a statement of the copper content expressed as a percentage. This, however, does not mean very much to one who has been accustomed to measure the strength of Bordeaux mixtures in terms of a formula, as already explained. The first thing necessary is to calculate the equivalent of crystallized copper sulphate; in other words, to determine what amount of crystallized copper sulphate would be required to prepare the mixture in question. This can be done very simply by the use of the factor 3.93, furnished by Mr. C. C. McDonnell, of the Bureau of Chemistry. Thus, when the percentage of copper (Cu) is given, as it usually is and properly should be in the analysis on the label, multiply this percentage by 3.93. If, however, in any case the manufacturer has not fully complied with the requirements of the law and has expressed the copper in terms of percentage of copper oxid (CuO), multiply this by 3.14, or if he has stated it in terms of copper hydroxid ($Cu(OH)_2$), multiply by 2.56. This in each case gives the equivalent percentage of copper expressed in terms of crystallized copper sulphate in the concentrated Bordeaux mixture. In order to calculate the copper sulphate when diluted ready for application, multiply the number of pounds of the concentrated Bordeaux mixture to be added to 50 gallons of water by the percentage of copper sulphate.

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[1] Rules and regulations for carrying out the provisions of the insecticide act of 1910. U. S. Dept. Agr., Office Sec. Cir. 34, 2d rev., 15 p. 1917.

[2] Inert and active ingredients of Bordeaux mixture. U. S. Dept. Agr., Office Sec., Insecticide Decision 6, 2 p. 1912.

Example.—A commercial Bordeaux paste which has been tested in some of our field experiments contains 5.92 per cent of metallic copper, according to the analysis given on the label. Therefore, if the preparation contains 5.92 per cent of copper, it contains the equivalent of 23.27 per cent of crystallized copper sulphate (obtained by multiplying 5.92 per cent by the factor 3.93 = 23.27 per cent). Thus, the paste contains copper equivalent to 23.27 per cent of crystallized copper sulphate. The label recommends that 8 pounds of this mixture be diluted with 50 gallons of water. Therefore, in order to calculate the amount of crystallized copper sulphate in 50 gallons of the diluted spray, take 23.27 per cent of 8 pounds, which equals 1.86 pounds.[1]

When this Bordeaux mixture is diluted for application it will contain in every 50 gallons an amount of copper equivalent to 1.86 pounds of copper sulphate. This is slightly weaker than a 2–2–50 formula.

USE OF THE TABLES.

For the use of those who are interested in a prepared Bordeaux mixture and do not wish to make exact calculations as herein explained, Tables I and II are presented.

TABLE I.—*Bordeaux formulas corresponding to the strength of Bordeaux mixtures produced when commercial preparations are diluted as directed.*

Metallic copper declared on label.	Approximate formula of Bordeaux mixture produced where the dilution is at the rate of 1 pound to—			
	10 gallons.	8 gallons.	5 gallons.	3 gallons.
1.5 per cent	0.3–0.3–50	0.4–0.4–50	0.6–0.6–50	1.0–1.0–50
2 per cent	.4–.4–50	.5–.5–50	.8–.8–50	1.3–1.3–50
2.5 per cent	.5–.5–50	.6–.6–50	1.0–1.0–50	1.6–1.6–50
3 per cent	.6–.6–50	.7–.7–50	1.2–1.2–50	2.0–2.0–50
3.5 per cent	.7–.7–50	.9–.9–50	1.4–1.4–50	2.3–2.3–50
4 per cent	.8–.8–50	1.0–1.0–50	1.6–1.6–50	2.6–2.6–50
4.5 per cent	.9–.9–50	1.1–1.1–50	1.8–1.8–50	2.9–2.9–50
5 per cent	1.0–1.0–50	1.2–1.2–50	1.9–1.9–50	3.3–3.3–50
6 per cent	1.2–1.2–50	1.5–1.5–50	2.3–2.3–50	3.9–3.9–50
7 per cent	1.4–1.4–50	1.7–1.7–50	2.7–2.7–50	4.6–4.6–50
8 per cent	1.6–1.6–50	2.0–2.0–50	3.1–3.1–50	5.2–5.2–50
9 per cent	1.8–1.8–50	2.2–2.2–50	3.5–3.5–50	6.0–6.0–50
10 per cent	2.0–2.0–50	2.4–2.4–50	3.9–3.9–50	6.5–6.5–50
11 per cent	2.2–2.2–50	2.7–2.7–50	4.3–4.3–50	7.2–7.2–50
12 per cent	2.3–2.3–50	2.9–2.9–50	4.7–4.7–50	7.8–7.8–50

By means of Table I any grower knowing the percentage of metallic copper, which, according to law, must be stated on the label, can determine at a glance approximately what formula will be produced when the product is diluted according to directions.

If the formula is not of the strength desired, the grower can determine in a similar manner from Table II approximately the number of pounds of the preparation it is necessary to add to 50 gallons of water to make either a 2–2–50, a 3–3–50, a 4–4–50, or a 5–5–50 for-

[1] It is realized that there is a slight error in these calculations, because the volumes occupied by the concentrated paste in the diluted commercial preparations and by the copper sulphate and lime in the case of homemade mixtures have been disregarded. This is done in order to avoid complicated computations; but the error thus involved is so small that it would have practically no effect on comparative values.

mula. Since these formulas cover practically every requirement this table should answer for all practical purposes almost as well as the more exact calculations.

TABLE II.—*Equivalent percentages of copper sulphate and number of pounds of concentrated commercial mixtures necessary to use in order to make Bordeaux mixtures of given formulas.*

Metallic copper declared on label.	Equivalent copper sulphate.	Pounds of concentrated mixture necessary to add to 50 gallons of water to make formula—			
		2–2–50.	3–3–50.	4–4–50.	5–5–50.
	Per cent.				
1.5 per cent	5.89	33.9	50.9	67.8	84.8
2 per cent	7.86	24.5	38.2	50.8	63.6
2.5 per cent	9.82	20.3	30.5	40.7	50.9
3 per cent	11.79	16.9	25.4	22.6	42.4
3.5 per cent	13.75	14.5	21.8	29.1	36.3
4 per cent	15.72	12.7	19.1	25.4	31.8
4.5 per cent	17.68	11.6	16.9	23.6	28.2
5 per cent	19.65	10.2	15.2	20.3	25.4
6 per cent	23.58	8.4	12.7	16.9	21.2
7 per cent	27.51	7.2	10.9	14.5	18.1
8 per cent	31.44	6.3	9.5	12.7	15.9
9 per cent	35.37	5.6	8.4	11.3	14.1
10 per cent	39.3	5.0	7.6	10.2	12.7
11 per cent	43.23	4.6	6.9	9.2	11.5
12 per cent	47.16	4.2	6.3	8.5	10.6

CALCULATION OF THE MONEY VALUES.

After the buyer has determined the amount of copper sulphate in the commercial Bordeaux mixture when diluted with 50 gallons of water, he can next calculate the money value of the ingredients of the mixture as compared with the homemade preparation. For example, the commercial paste above referred to contains 1.86 pounds of crystallized copper sulphate when diluted with 50 gallons of water. The present cost of copper sulphate varies from 11¼ cents in 450-pound lots to 20 to 30 cents in small quantities, depending on the dealer from whom it is purchased. In this calculation it will be assumed that an equal amount of lime which is worth in barrel lots 1 cent per pound will be included in each 50 gallons of spray. Therefore, in 50 gallons of this commercial spray the copper sulphate will be worth from 20.92 to 55.8 cents (1.86 pounds at 11¼ cents = 20.92 cents and 1.86 pounds at 30 cents = 55.8 cents) and the lime 1.86 cents (1.86 pounds at 1 cent = 1.86 cents). This makes a total of from 22.78 to 57.66 cents, the value of the essential ingredients of the commercial paste when diluted with 50 gallons of water. In other words, one could buy the material to make 50 gallons of Bordeaux mixture equal in copper content to this one for 22.78 to 57.66 cents. This mixture sells on the market for 10.4 to 30 cents per pound, depending on the quantity purchased. At the dilution recommended, therefore, 8 pounds to 50 gallons of water, this would cost from 83.2 cents to $2.40 for this quantity of the diluted spray. A

homemade 4–4–50 Bordeaux mixture would cost from 45 cents to $1.20 for the copper sulphate and 4 cents for the lime, or a total of 49 cents to $1.24.

Similar figures for another commercial paste, which was found to contain copper equivalent to 3.17 pounds of crystallized copper sulphate to 50 gallons of the diluted mixture, would work out as follows: 3.17 pounds of copper sulphate, at 11¼ to 30 cents = 35.66 to 95.1 cents and 3.17 pounds of lime at 1 cent = 3.17 cents. In the case of this preparation it would cost the grower from 38.83 to 98.27 cents to buy materials with which to make 50 gallons of a homemade Bordeaux mixture containing an equivalent amount of copper. If, on the other hand, he buys this prepared mixture which sells on the market at from 15 cents per pound in 500-pound lots to 35 cents in 1-pound lots, it will cost him when used as directed from $1.20 to $2.80 for the 8 pounds to make 50 gallons.

CALCULATION OF LEAD ARSENATE.

There is another class of commercial Bordeaux pastes and powders in which an insecticide (usually lead arsenate) has been added by the manufacturer ready for dilution, and when their value is computed it is necessary to calculate the value of the insecticide as well as that of the copper sulphate and lime.

In this connection it should be noted that in the case of such preparations the Insecticide Act requires the statement of inert or active ingredients, as already explained, and also a statement of "the total amount of arsenic present (expressed as per centum of metallic arsenic)" and "the amount of arsenic in water-soluble form (expressed as per centum of metallic arsenic)."[1]

The only feasible method of complying with these requirements is for the manufacturer to include some such statement on his label as the following:

> Active ingredients: Dry lead arsenate, —— per cent; copper of Bordeaux mixture, —— per cent.
> Inert ingredients: —— per cent.
> Aresenic in water-soluble form (expressed as per centum of metallic arsenic), —— per cent.

The value of the Bordeaux mixture in this preparation may therefore be calculated in the manner already described. For all practical purposes the percentage of lead arsenate in terms of lead arsenate paste may be obtained by multiplying the percentage of dry lead arsenate by 2, since 1 pound of dry lead arsenate is practically equivalent to 2 pounds of lead arsenate paste; or, in other words, lead arsenate paste usually contains approximately 50 per cent of water. If, however, the grower has been accustomed to purchase his lead

[1] Rules and regulations . . . Op. cit., p. 14.

arsenate in the dry powdered form, the percentage of this is given on the label.

Example.—A commercial Bordeaux lead arsenate which has been tested by the writers claims 1.50 per cent of metallic copper (Cu) and 18.25 per cent of dry lead arsenate. This preparation, therefore, using the method here described, when diluted 8 pounds to 50 gallons, contains 0.47 pound of crystallized copper sulphate. As stated, it contains 18.25 per cent of dry lead arsenate or twice this amount (36.5 per cent) of lead arsenate in the paste form; multiplying these figures by 8, the equivalent amounts of dry and paste lead arsenate contained in 50 gallons of the diluted spray may be obtained, which are 1.46 and 2.92 pounds, respectively. This preparation, therefore, will contain crystallized copper sulphate worth from 5.28 to 14.10 cents, lime worth 0.5 cent, and lead arsenate selling on the market at approximately 35 cents for the dry form and 17.5 cents per pound for the paste, worth 51.10 cents, making a total of 56.38 to 65.20 cents. It sells for 12 cents a pound in 500-pound lots to 30 cents a pound in 1-pound lots, and therefore would cost the purchaser for every 50 gallons of diluted spray from 96 cents to $2.40.

VARIATIONS IN COMMERCIAL MIXTURES.

In order to give some idea how different brands of commercial Bordeaux mixture may be expected to vary in this respect, a number of samples used by the writers in their special tests for the Insecticide and Fungicide Board are given below. They were found to contain, respectively, when diluted with 50 gallons of water according to directions, copper equivalent to 0.6, 1.5, 0.9, 1.8, 1.82, 0.7, 3.71, and 1.9 pounds of crystallized copper sulphate. The above calculations are based on analyses made by the Bureau of Chemistry.

It is evident, therefore, that the money value of various commercial Bordeaux mixtures will be found to show considerable variation. It should, therefore, help the grower to have the above information, which enables him to calculate how much it will cost for material to make up a homemade Bordeaux mixture containing copper sulphate equivalent to the particular brand which he anticipates purchasing.

OTHER FACTORS DETERMINING VALUE.

It should be noted that in calculating the money value of the above preparations as compared with the actual cost to the consumer only the value of the ingredients has been considered. No allowance has been made on the one hand for the overhead charges necessary to the manufacture and distribution of the goods, such as cost of preparing, packing, advertising, and selling, nor, on the other hand, has allowance been made for the cost to the grower of preparing his homemade preparation. If such allowances were made, doubtless less difference would be shown between the cost of the homemade and the commercial fungicides. The cost of labor and equipment for preparing homemade Bordeaux mixtures will vary with the individual and with varying circumstances. Furthermore, the kind of labor

available is an important consideration. If incompetent or unreliable help must be employed to prepare the homemade mixture the chances for mistakes are greater than in the case of a good proprietary preparation manufactured by a reliable company. None of these factors are discussed here, but they should be considered by each grower according to his individual circumstances.

PHYSICAL PROPERTIES DETERMINING VALUE.

It is also true that there are other factors, aside from the copper content, which are important in determining the real value or efficiency of Bordeaux mixtures. In fact, our tests on the whole seem to indicate that the physical properties of the preparation are in many cases even more important that the quantity of copper present. Of course, there must be sufficient copper to do the work. On the other hand, a preparation containing a large amount of copper, but coarse and granular in texture, with poor spreading and sticking qualities, can not be expected to give good results in cases where a good fungicide is required.

Figure 1 illustrates the results of some tests made to determine the physical or mechanical condition of a number of proprietary Bordeaux mixtures and of a homemade preparation for comparison. The preparations were diluted with water as directed for use, poured into glass cylinders, and shaken thoroughly. The illustrations show the relative ratio of subsidence. It will be noted that the fresh homemade Bordeaux mixture in cylinder *a* has remained in suspension much better than any of the others and that there was considerable variation among the commercial preparations in this respect. The precipitate in cylinder *c* went to the bottom in two minutes after shaking. Such a preparation would certainly require especially good agitation and, even so, its physical properties would be very poor. It is interesting to note that after standing 48 hours and being reshaken, the homemade Bordeaux mixture settled as quickly as some of the commercial preparations, thus showing that on standing for that length of time it deteriorates, becoming more like the commercial preparations in its physical properties.

In general, it is believed that the rate of subsidence, as shown by these tests, is a fairly good criterion by which to judge the physical properties of Bordeaux mixtures, though it has not yet been determined how infallible this method is in all cases. It is true that some commercial preparations which settle much more quickly than fresh homemade Bordeaux mixture are at the same time quite fine in texture and appear to have very good adhesive properties and, so far as the writers could observe in the absence of chemical tests, adhered as well as the homemade mixture.

It is certain, however, that all preparations showing very rapid subsidence will require at least very thorough agitation, and it will

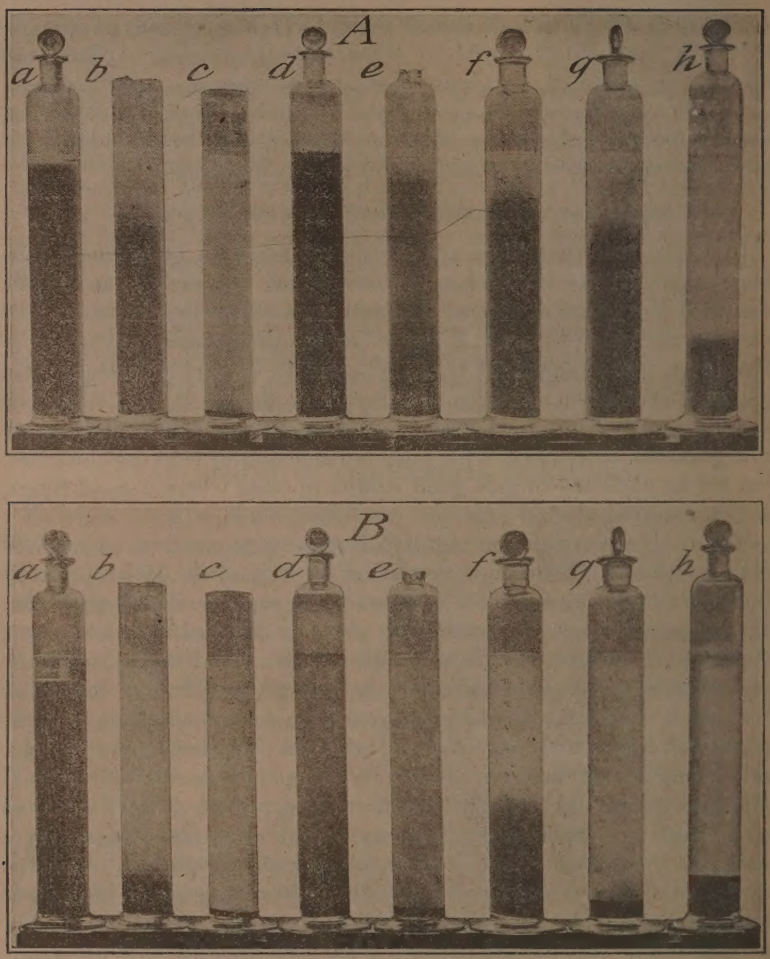

FIG. 1.—Cylinders containing various brands of commercial Bordeaux mixtures (*b* to *h*) compared with a homemade Bordeaux mixture, 4–4–50 formula (*a*), showing relative subsidence as an indication of their physical and mechanical properties: *A*, Photographed 2¼ minutes after shaking; *B*, Photographed 8 minutes after shaking.

be well when they are used to see that the sprayer is provided with a very efficient agitator. In other words, in those commercial Bordeaux preparations which the writers have examined in this way, more thorough agitation is necessary than in the case of a good, fresh, homemade mixture. On the other hand, if some of the best commercial preparations are properly applied and in sufficient quantities to furnish the necessary amount of copper, there is no doubt that good results can be obtained; and if any grower for any reason finds

it more practicable or prefers to purchase a prepared Bordeaux paste he will probably obtain good results from its use, provided he selects a brand that shows good physical properties, which can be determined readily by the subsidence tests already described, and uses it at a dilution which furnishes sufficient copper to control the diseases which he wishes to combat. In this connection it may be well to add that, as has been shown, the dilutions recommended by many manufacturers for the use of their Bordeaux preparations would furnish much less copper than would be used in a homemade mixture, and in some cases the amount would not be sufficient for satisfactory control of the diseases in question. It would therefore be well for the grower, knowing what strength of homemade Bordeaux mixture he should use to combat the diseases of his crops, to determine by reference to Table II or to calculate by means of the methods of computation given in this bulletin just what dilution of the commercial paste would be necessary to furnish the desired formula, instead of depending entirely on the manufacturer's recommendation.

STANDARD FORMULAS NECESSARY TO INSURE SATISFACTORY RESULTS.

In this connection there also arises the question, "Can the grower afford to economize by using a weaker mixture than is commonly advised for the various diseases which require Bordeaux treatment?" To judge from our experience and observations, it is probable that in many cases when infection conditions are mild a Bordeaux mixture containing considerably less copper sulphate than is commonly advised for the various diseases for which this mixture is recommended would give very good control, provided its physical properties are good and it is thoroughly applied. It is also probable that considerable benefit will be derived from the use of the weak mixture even when the infection is quite severe; but under such circumstances the disease will not be satisfactorily controlled, and the resultant loss would in many cases much more than offset the amount saved by economizing on copper sulphate during the seasons of mild infection.

Spraying is a question of insurance, and the grower must decide whether he wishes to insure his crop wholly or only partially against fungous diseases. He might partially insure his crop by spraying with a Bordeaux mixture containing much less copper than is usually recommended. The conditions which follow may require only a weak fungicide for satisfactory control; but one can not foretell when such conditions will occur, and the spraying must be done in advance as a preventive measure. It is therefore safer, if the grower wishes to make sure of the best results, to use the amount of copper sulphate commonly advised by experts for control under epidemic conditions.

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